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Just-in-Time Traffic Model Adaptation to Non-Recurrent Incidents

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Abstract

Traffic networks are complex systems, where tens of thousands of vehicles interact dynamically. Proper performance of traffic networks has great socio-economic impacts on urban environments. As such, cities worldwide invest great resources in designing and implementing effective traffic management strategies, in which reliable prediction schemes play a main role.

Under typical road conditions, traffic tends to follow repeated patterns, and can thus be effectively predicted. Alas, short-term traffic prediction models often deteriorate greatly under non-recurrent traffic disruptions – such as road accidents or unforeseen weather extremities – just when accurate prediction is most needed for effective incident management. The problem is further exacerbated by the typically low availability of system-wide observability in traffic networks.

Consequently, immediate adaptation of short-term traffic prediction models to sudden disruptions has so far been a largely unsolved problem. The key issue is that when an incident happens, the correlation structure between target variables and predictors changes abruptly, in a manner which is unique to the incident characteristics. So far, no systematic method has been found for updating traffic prediction models based mainly on real-time information about the incident itself.

Nowadays, however, In-Vehicle Monitoring Systems (IVMS) are increasingly penetrating vehicle markets worldwide. IVMS devices constantly monitor and report the status of the vehicles where they are installed, and in particular, deliver distress signals in case of break down. The global adoption of IVMS technologies thus offers unprecedented levels of real-time network observability.

In this work, we formulate a novel, model-based framework for timely adaptation of traffic prediction model under incidents, by leveraging real-time IVMS signals from affected vehicles. Our methodology is to simulate multiple "what-if" scenarios of the affected road, based on information in the received IVMS signals. The data obtained from the simulations is then fed to data-driven Machine Learning methods, which yield an adapted prediction model. The new, just-in-time model is better fit to predict how traffic evolves shortly after the onset of the particular incident.

We experiment our framework in a case study of a highly utilized Danish highway, and the results show that our approach potentially improves traffic prediction in the first critical minutes of road incidents. Because only a few dozens of simulations are required, such real-time computation is well within the capacity of commercially available computational clusters. Our findings suggest that given immediate incident information, the hitherto unsolved problem of just-in-time model adaptation is presently becoming tractable.

Keywords

Intelligent Transportation Systems (ITS), short-term prediction, real-time model adaptation, model-based and data-driven Machine Learning